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Original article

The Use of Drones in Agricultural Production

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Abstract

The drones called mainly unmanned aerial vehicles (UAVs) have been commonly used recently in agricultural production in all part of the world because of reducing costs for the hardware and the software technology for their production. Moreover, UAV's gave opportunities such as reaching much faster and efficient in emergency situations, allowing access to places where humans can't reach etc. Therefore, UAVs are used in many parts of our life not only for agriculture but also in traffic surveillance, military operations, disaster management, border-patrolling, aerial image georeferencing, courier services, firefighting as well as monitoring of wildlife, nature, sky life etc. In the agriculture, the UAV's are used mostly for monitoring the crop production using spectral imaging on each period of time in order to identify the problems on the field such as water shortage and diseases, tracking animals, using cameras and herding them with creating sounds produced by the UAV's, spraying to the field with pesticide, fungicide and water by equipping spraying kit on a UAV, generating the strong winds by the propellers of the UAV increasing pollination in the hybrid plant production as well as separating the small harmful bugs from the plants etc. The UAV's contribute a lot more to the agricultural sector, if the right implementations and researches are done. However, using new implemented lightweight materials to increase the endurance of the UAV, developing new type of lenses and sensors which can identify other diseases on plants or animals which can't be seen by the current equipment and equipping a granule spreader on a UAV so that it can distribute the seeds on the field much faster than a tractor.

Keywords: Agriculture, UAVs, Crop Production, Animal Production, Remote Sensing.

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INTRODUCTION

UAV technology with utilizing from remote sensing, and data analytics has contributed recently to improve agricultural research and applications giving the farmers and researchers accurate information by monitoring of their fields from the air for better productivity and sustainability in the agriculture. With this advancements, many useful data were obtained using multiple sensors and platforms to monitor plant health and development during their growing seasons on daily or weekly basis including, soil quality, climatic changes, pest control, crop irrigation, animal gathering and counting, observing their eating habits, geo-fencing, and other agriculture-related activities with developing data collections to communicate among researchers, algorithms/programs for analyzing and sharing these data, flight paths for insuring optimal ground coverage, etc. (Yinka-Banjo and Olasupo, 2019; Zhang and Kovacs, 2012; Schmale III et al., 2008; Gonzalez and Mcfadyen, 2018; National Research Council, 1997; Arroyo et al., 2017).

Furthermore, some progress was also made to observe and estimate on crop improvements on some important yield characteristics especially for comparing varieties and plant stress traits such as drought and heat tolerance, disease and pest resistance, canopy cover, greenness index, earliness, seedling vigor, growth curves, growth patterns, stand counts, plant height, total biomass, seed yield, plant height, etc. in different crops such as maize, Cotton, Sorghum, wheat and some vegetables (Yinka-Banjo and Olasupo, 2019; Zhang and Kovacs, 2012; Schmale III et al., 2008; Gonzalez and Mcfadyen, 2018; Gevaert et al., 2014; Perry et al., 2012).

On the other hand, in some agronomical managements, some applicable and practical solutions by UAV technologies for producers were also developed such as identifying herbicide-resistant and plants, injuries during herbicide spraying, assessing defoliation times, nutrient optimization, determining suitable irrigation times, and measuring root rots and leaf rusts and diseases pressure and identifying management of plant stress via different soils. Similarly, some observation on pastures and grasslands for better livestock production such as measuring plant mass, canopy cover, animal (livestock and wildlife) counts, nutrition value, weed invasion, herding, scouting, etc. and also animal science; such as tracking of animal health status, behaviors, feed-conversion performances, responses to environmental stresses, and biosecurity threats on animals (Yinka-Banjo and Olasupo, 2019; Zhang and Kovacs, 2012; Schmale III et al., 2008; Gonzalez and Mcfadyen, 2018; Gevaert et al., 2014; Perry et al., 2012; Darack, 2012).

The Uses in Crop Production

UAV assists the farmer via analysis of captured remote images for also planning planting patterns, irrigation and fertilizer needs as well as weed control in their fields to improve seed with less fertilizer and pesticide use to protect nature (Pena et al., 2013; Torres-Sanchez et al., 2013; Arroyo et al., 2017).

In these studies, the spatial and spectral images were evaluated in maize and sunflower crops for weed control, seedlings and descriptions via multi spectral cameras. Nowadays, UAV planting technologies reduce agronomical application costs by up to 85% by performing several activities at the same time. In another study, some yield traits such as Leaf Area Index (LAI) and fractional vegetation in different growth periods were evaluated in sorghum hybrid yields by multi spectral sensors to collect images by high resolution images from UAV with analyzing relationships among Normalized Difference Vegetation Index (NDVI) and LAI data to estimate better plant population density in sorghum (Shafian et al., 2018). In another study (Zhang et al., 2018) in corn, UAV-based image algorithms were used for field scale to measure the distances among corn plants at field to improve seed yields with reducing fertilizer and pesticide applications as well as yield estimations.

Among the most valuable contribution of UAVs into agricultural production is on spraying of pesticide, herbicide and liquid fertilizers at any vegetation period of plants, especially late vegetation periods when plants have higher heights. Furthermore, if we want to use tractor, we have to arrange plant density based on tractor wheel diameter, until the plants are 50-60 cm high. After this plant heights, there is no possibility for farmers to apply any agricultural input. Therefore, in recent years UAV companies interested in agricultural production mostly focus on these spraying tasks in not only field crops but also horticulture crops as well as forest trees. Agricultural UAVs present opportunities to farmers to apply and cover huge lands in shorter time intervals automatically, adjusting their heights even in not homogeny fields due to both plants and also topographical reasons utilizing from sensors (Yinka-Banjo and Olasupo, 2019).

On the other hand, UAV spraying offers more advantages such as saving time and cost, efficient applications in help for plants and soil as well as changeable amounts based on plant growths and needs and also soil nutrition availabilities in different parts of fields properly utilizing previous analyzed maps, also reducing amounts of harmful chemicals (herbicide, pesticide, etc.) to environments. Many studies were applied also in this context for applying pesticide etc. utilizing from infrared thermal imaging from high resolution cameras to evaluate and improve droplet size and diameter, spray pressure flight speed, for better and proper applications as well as getting accuracy for UAV propeller airflow direction during the aerial spraying to obtain better yields from crops. Recent studies show that it could be possible that these spot spraying application reduce chemical herbicide amounts until up to 90% (Ly et al., 2019; Yallappa et al., 2017; Hentschke et al., 2018; Xiongkui et al., 2017).

The Uses in Crop Monitoring

Another important promising use of current and future potential of UAVs is monitoring of plant growth in different crop vegetation periods with thermal imaging cameras to determine the responses of plant to different environmental stresses and actions as well as agronomical applications in the large fields to define accurately plant needs normal and unpredictable weather conditions for better yield in the future (Guo et al., 2012). On the other hand, farmers could determine soil moisture, water status and plant water stress for precise irrigation time and practices as well as accurate water management using of UAVs with thermal image cameras in the fields and orchards (Baluja et al., 2012; Khanal et al., 2016; Gonzalez-Dugo et al., 2013). Crop monitoring for plant health is another promising application of the UAV technology. Remote sensors and thermal cameras are attached to UAVs to detect fungal and other diseases in the plants (Piug et al., 2015; Casbeer et al., 2011). Additionally, UAVs make possible the performance of bird control and scaring wild animals in the fields and orchards (Yinka-Banjo et al., 2018).

In another study (Santesteban et al., 2017), researchers used Remote Sensing and Mapping Single X8 type UAV with multi-spectral and thermal cameras again to estimate the instantaneous and seasonal variability of plant water status in vineyards. Additionally, in another study (Zarco-Tejada et al., 2013), researchers used almost same type UAV and system again in vineyards to evaluate leaf carotenoid content. In another study (Vega et al., 2015) researchers used sunflower crop monitoring with single quadcopter UAV to obtain multi-temporal images with multi-spectral cameras. The researchers used an innovative procedure for a high-throughput and detailed 3D monitoring of olive tree plantations with visible-light and multi-spectral camera attached to Quadcopter UAV (Torres-Sanchez et al., 2015).

The Uses in Animal Production and Monitoring

UAVs are commonly used in the traditional livestock production in many parts of the world nowadays in both in cattle and also sheep and goats. UAVs with heat detecting infra-red cameras and thermal imaging are widely used in livestock production for hence monitoring, daily head counts in large grassland areas (Chamoso et al., 2014; Vayssade et al., 2019), observing feeding behaviors, animal counting by image recognition with flying across the fields (Havens and Sharp, 2015), observing animals in the huge grasslands without causing conflicts. The authors mentioned that the accuracy was obtained on about 73% for counting and about 78% for animal tracking.

On the other hand, the infra-red cameras on UAVs are used to monitor animal health such as fever (Havens and Sharp, 2015; Texas A&M AgriLife, 2019). Animals movement of herds and also tracking of a specific tagged animal by farmers (Webb et al., 2017) as well as monitoring endangered animals or wild animals for research purposes with UAVs having normal or IR cameras (Nyamuryekunge et al., 2016) is current issues in the new era for animal science and production. Additionally, UAVs have started to be used also for gathering and mustering of animal herds utilizing from sirens, etc. instead of shepherds and sheep dogs or other traditional guards such as cowboys or motorcycles in the large grazing lands. UAVs aren used also for guiding of animals for feeding, milking, drinking of water areas because of being risks free, cheaper costs and reaching to inaccessible areas (Andonovic et al., 2018; Jayme Garcia, 2018). Furthermore, UAVs are used for geo-fencing, virtual border for monitoring of animals in the grasslands to limit for grazing areas and movements of animals out of boundaries. In these sensors via low cost GPS is being notified the farmer (Gonzalez and Mcfadyen, 2018; Jayme Garcia, 2018).

In one study (Noriega and Anderson, 2016) researchers continued to work on optimizing UAVs for precise agriculture and developed a path planning method for minimizing the time required during the scanning period over fields for monitoring with multi-spectral camera attached on Octocopter. Similarly, the researchers in another study (Tokekar et al., 2016), tried to solve the problem of maximizing the number of points across the fields visited by the Octocopter UAV with remote sensing having multi-spectral camera. In another study (Christiansen et al., 2017), the researchers improved the field surveying in wheat fields by designing and testing a Quadcopter UAV for agricultural mapping, the same was performed by Doering et al. (2014).

The Other Uses for Agricultural Research Purposes

The profitability in the agricultural production is decreasing year by year both related to severe environmental conditions and also to increasing of the amounts of agricultural inputs used as well as their costs. Therefore, it needs to reduce these costs and also reduce climatic stress on the plants in agricultural systems. In this case, UAVs and remote systems allow the producers and agricultural scientists for determining of how plants response to these abiotic stresses in large scale in different conditions as well as to biotic responses accurately such as pest and diseases, also for applying lower amounts of chemicals in a proper way

UAVs technology help the agricultural researchers and farmers for taking cropping decisions, providing multi-dimensional climatic, soil and crop data for precision agriculture as well as about economic and environmental aspects of farming (James and Jones, 2017; Redmond and Shamshiri, 2018).

In the current situation, the agriculture is facing several challenges such as high labor use, inputs and environmental pressures. It seems that one of the profitable way for increasing of farmer incomes is related to increased use of UAVs, that are capable of gathering highly detailed crop data for accurate decisions; reducing the production costs and helping in marketing strategies leading to increase in the crop yields (Stein, 2017). The researchers generate new models with the aim to increase the functions of agricultural systems combining UAVs gathered data with GPS, GIS, remote sensing, and geomapping sensors for precision agriculture and accurate yield estimations by monitoring crops, soils and other climatic data (Rohit Sarma, 2018; Hovhannisyan, 2018).

Fertilization is key issue in crop production for higher yields so the determination of plant nutrition requirements in the cropping systems properly is so important for precision agriculture. Researchers used the data about nitrogen levels and biomass in barley gathering by UAVs hyperspectral camera images and utilized from image scanning and analyzing software for orientation of the obtained images in one study. Based on the biomass estimation via 3D RGB images, plant nitrogen content was determined properly, and based on itit was further generated accurate estimation models for obtaining better yields (Roope Nasi, 2018). In another study, the researchers developed a model to estimate Nitrogen nutrition level in crops using agricultural UAV as Quadcopter (Arroyo et al., 2017). Chlorophyll composition of plants is one of the most important characteristics for plant vegetation as well as crop yield. Therefore, the process how plant accumulate chlorophyll and what is its chemical composition, as well as the y leaf area index (LAI) during this period interest more plant researchers. In another study, it was measured the chlorophyll content of the corn plants via multispectral and hyperspectral sensors as visible, near-infrared, and red edge frequencies using eBee AG Sensefly UAV. The researchers found that LAI data and the captured images in the green, red, red-edge, and NIR bands by Pix4Dmapper Pro program are incorporated with plant chlorophyll contents.

Hence, a predictive algorithm for canopy chlorophyll content was generated then using UAVs imagery was possible to detect higher canopy plant mapping accurately in the fields (Simic Milas, 2018). In another study (Jannoura et al., 2015), the researchers evaluated crop biomass of pea and oat using true color aerial photographs with (teleoperation) RGB camera with UAV as single hexacopter.

The weeds are one the most limiting factors for profitable agricultural production in almost all crops. For weed control are mostly used chemical herbicides, which are another pollutant hazard for our nature (Torres-Sanchez et al., 2013; Shah et al., 2018). The researchers used an UAV equipped with TetraCam mini-MCA6 multispectral camera for detecting weeds in crops. Based on the study results, they proposed an optimal flight plan at 60 m with 10% security margins in cruising mode AGL to obtain maximum spatial resolution and spectral discrimination (Fancisco-Javier and Mesas-Carrascosa, 2015).

In another study (Alsalam et al., 2017), researchers controlled weed by spraying the fields using a modular and generic system with remote sensing in single quadcopter utilizing from ultrasonic RGB cameras. In another study (Torres-Sanchez et al., 2013), by quadcopter UAV, researchers used point-and-shoot and multi-spectral cameras for site-specific weed management in sunflower to determine the specifications and configurations. In another study (Faical et al., 2017), the researchers tried to improve UAV spraying management with a computer-based system for easy control.

Similarly, the plants counting and determining population density as well as classify vegetative cover in the fields are important issue for precise agriculture. In one study, UAV Falcon 8 octocopter equipped with three Sony Alpha 6000 cameras was used to detect vegetation in the field surface capturing images at the RGB, red-edge, and NIR spectrums then orthomosaic images were generated with 3D mesh. The researchers obtained higher accuracy to classify the orthomosaics images captured in the RGB spectrum then they concluded that UAVs has great potential for classifying vegetation in the field (Jessica and Tay, 2018).

The detection of soil types and collecting soil samples is a key issue for higher crops yields and recently UAVs were used to determine accurate sampling patterns based on soil types. The researchers explored the novel method using DJI Phantom 4 Pro to capturing RGB images from newly plowed fields. Based on clustered spatial and color results, UAV imagery and AR was found successful method for collecting soil samples for precision agriculture (Huuskonen, 2018). On the other hand, UAVs equipped with thermal sensors offer very valuable information to detect moisture content of the crops, fruit trees in the orchards as well as of soil to schedule accurate irrigation for precise farming (Long et al., 2016). In another study (Allred et al., 2018), researchers used VIS, NIR, and TIR imagery for drainage pipe in the fields to evaluate corn and soybean plants using multi-spectral and thermal cameras for remote sensing and mapping single fixed-wing type UAV.

Conclusions And Future Directions

For crop production, agricultural UAVs will provide many benefits. First of all, it will lead to change plant frequency of the field because most of the crops are planted depending on a tractor wheel. So, the frequency will be increased which will initially increase the food production. Secondly, using an UAV for spraying pesticide, fungicide and water will have a great effect on plant protection because using the generated map by spectral imaging, the UAV will only spray on the specific area of the field which requires these chemicals and water which will initially reduce the cost and overusing pf substances that can harm the environment.

Agricultural UAV’s will help farmers and agricultural engineers for tracking plant growth, water shortage and identifying diseases using an equipped spectral camera. This will provide information about the plant and soil health which is helpful for taking immediate action when it is required so that all crops will stay healthy. It can also be used for monitoring the animal’s health, counting, herding and gathering. This will grant a really good benefit especially for tracking large group of livestock in the huge grasslands. Because the UAVs consume electric and doesn’t release any harmful chemical gases, it makes them environmental friendly vehicles. Also, if a rotary-wing configuration is used, the generated thrust from the propellers will separate the little harmful insects from the plants while hovering on the field.

In the future using new implemented lightweight materials will increase the endurance of the UAV which will enable the UAV to accomplish the task without taking any constant battery brakes. Developing new type of lenses and sensors will help identifying other diseases or parasites on plants or animals which are hard to detect by current hardware. Equipping a granule spreader on a UAV will cause that it can distribute the seeds on the field much faster on the field especially for rough terrains and big fields such as forest planting. The agricultural UAVs will have autonomous task sequence such as spraying required water or pesticide on specific areas according to the generated map while following the route on the field.

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Additional Declaration

Research and publication ethics principles were comply with in this study. Authors contributed equally to the study.

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